§62. Extension of Neutral-Beam-Heated Long-Pulse Discharge

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Long-pulse steady-state operation is one of the major objectives of the LHD, and long-pulse neutral beam heating has been carried out with a negative-ion-based NBI. In the second campaign (1998), where the magnetic field strength was 1.5 T, a stationary plasma with a density of 0.3 x 10^{19} m^{-3} was sustained for 21 sec at an injection power of 0.6 MW. On the other hand, plasma relaxation oscillation, so-called "breathing", was observed for 20 sec at a higher density, and high-density stationary plasmas were not obtained for a long duration [1]. In the third campaign (1999), the magnetic field strength was raised to 2.75 T, and the pulse duration of the NBI long-pulse discharges was extended with higher densities.

Figure 1 shows the time evolution of various plasma parameters for an long-pulse NBI plasma extended to 80 sec. The injection energy and power are 100 keV and 0.5 MW, respectively, and the LHD magnetic field strength and the axis position are 2.75 T and 3.6 m, respectively. The density was controlled by manual operation of helium gas-puffing, and the line-averaged electron density was maintained at (1.5 – 2.0) x 10^{19} m^{-3}. The wall pumping effect is recognized and enables the density control with the gas-puffing for 80 sec. The central ion temperature, measured by the Doppler broadening of TiXXI, is around 1.5 keV, and the radiation power is kept at a low level during the shot.

The plasma density can be maintained constant by feedback control of the gas-puffing. Figure 2 shows the time evolution of various plasma parameters for a high-density stationary shot heated by the NBI for 10 sec. The injection energy and power are constant of 120 keV and 1.4 MW, respectively. A high-density plasma of 5 x 10^{19} m^{-3} is sustained stationary by the feedback control with hydrogen gas-puffing, and the other plasma parameters are almost in a steady state. The estimated energy confinement time, τ_E^{exp}, is increased with an increase in the density, and is about 1.5 times as long as the international stellarator scaling ISS95, τ_E^{ISS95}. This enhancement factor is similar to that in the short-pulse experiments for 1 - 2 sec, meaning that the discharge duration can be easily extended keeping the plasma confinement properties in the short-pulse shots.

[1] Y. Takeiri, *et al.*, Plasma Phys. Control. Fusion **42**, 147 (2000).

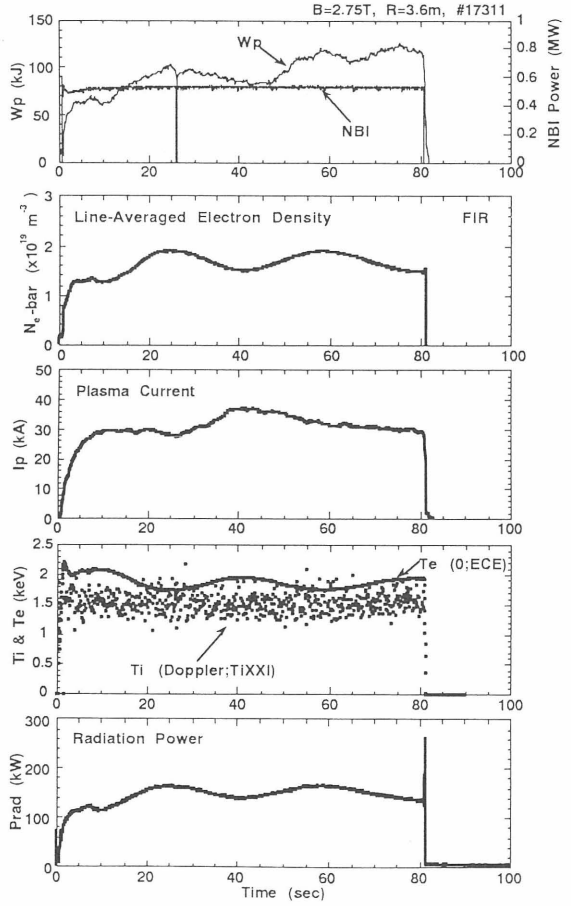

Fig. 1. Time evolution of various plasma parameters in 100 keV - 0.5 MW - 80 sec shot.

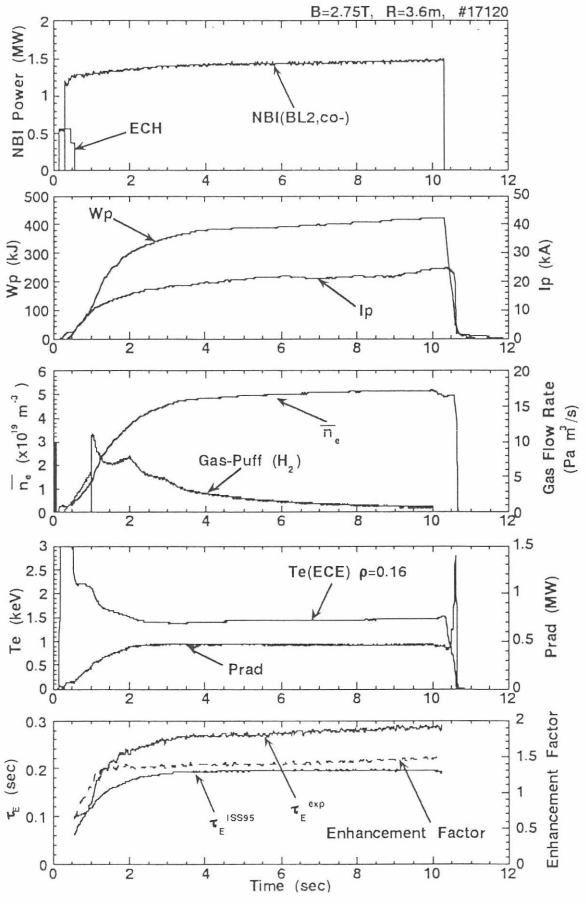

Fig. 2. Time evolution of various plasma parameters in high-density stationary shot for 10 sec.